CHAPTER 1

INTRODUCTION

1-1. Purpose and scope. This manual presents mobilization procedures for the design of Army airfield rigid pavements and overlay pavements that incorporate a portland cement concrete layer in either the overlay or base pavement.

1-2. General. The design procedures presented herein apply to the following types of pavements, design loadings, and design parameters.

a. Types of pavements. A rigid pavement is considered to be any pavement system that contains as one element portland cement concrete, either nonreinforced or reinforced.

b. Design loadings. This manual is limited to Army airfield pavement design requirements for aircraft during a mobilization situation. Discussions and design charts herein are confined to the pavement design classes shown in table 1-1.

c. Design parameters. The procedures in this manual express pavement thicknesses in terms of five principal parameters: design load, generally stated in the design directive; foundation strength; concrete properties; traffic intensity; and traffic areas. The foundation strength and concrete properties normally depend upon many factors that are difficult to evaluate.

1-3. Definitions and symbols. The following terms and symbols are commonly used in this manual. Other more specific or lesser used symbols will be defined where used.

a. Definitions.

(1) Base pavement. The existing pavement (either rigid or flexible) on which an overlay is to be placed.

(2) Inlay pavement. Rigid pavement used to replace the interior width of existing runways and as a method of rehabilitation or upgrading of existing pavement.

(3) Stabilized soil. The improvement of the load-carrying and durability characteristics of a soil through the use of admixtures. Lime, cement, and fly ash, or combinations thereof, and bitumens are the commonly used additives for soil stabilization.

(4) Modified soil. The use of additives to improve the construction characteristics of a soil. However, the additives do not improve the strength of the soil sufficiently to qualify it as a stabilized soil.

Table 1-1. Pavement Loading Classifications*

Class	Planned Aircraft Traffic	Design Basis
I	Rotary- and fixed-wing aircraft with maximum gross weights equal to or less than 20,000 pounds.	Class I pavement will accommodate all Army fixed-wing and rotary wing aircraft except the CH-47B/C, CH-54A/B and the proposed Heavy Lift Helicopter. This pavement design will be used for all airfield facilities other than where Class II, III, or IV pavement design is required. The design is based on 25,000 passes of the most critical aircraft in this class.
II	Rotary-wing aircraft with maximum gross weights between 20,001 and 50,000 pounds.	Class II pavement design will be used for facilities designated to accommodate the CH-47B/C and CH-54A/B aircraft. The design is based on 25,000 passes of the most critical aircraft in this class.
III	Fixed-wing aircraft with maximum gross weights between 20,001 and 175,000 pounds and having one of the indicated gear configurations.	Class III pavement design is suitable for a large number of fixed-wing aircraft currently in inventory. The design is based on 5,000 passes of the most critical aircraft in this class. Design criteria relates only to aircraft having one of the following gear configurations: Single wheel, tricycle, 100 psi tire pressure. Twin wheel, tricycle, 28-inch c. to c. spacing, 226 square inches contact area each tire.
IV	Multiple wheel fixed-wing and rotary-wing aircraft other than those considered for Class III pavement.	Class IV pavement will be of special design based on gear configuration and gear loads of the most critical aircraft planned to use the facility. Class IV pavement design will also be used for facilities normally being designed as Class III pavements when over 5,000 passes of the most critical aircraft in that category are anticipated during the expected life of the pavement. Designs for special gear configurations shall be based on design curves provided in Air Force Manuals. Curves for Air Force Light, Medium, Heavy load and short field are included for reference.

* Type B traffic areas include all runways, primary taxiways, warmup aprons, and traffic lanes across parking aprons. Type C traffic areas include shoulders, overruns, secondary (ladder) taxiways, parking aprons except for traffic lanes, and other paved areas used by aircraft not included in Type B traffic areas. Type A and D traffic areas will not be considered for Class I, II, and III pavement loadings under mobilization design criteria.

(5) CE maximum density. The measure of a soil density described in MIL-STD-621, Test Method 100.

(6) Traffic areas. Areas used to divide pavement into groupings in accordance with traffic usage.

(7) Aircraft pass. The passage of an aircraft on the pavement facility being designed.

(8) Design aircraft pass level. The number of aircraft passes for which an airfield is to be designed.

(9) Coverage. A measure of the number of maximum stress repetitions that occur at a particular location in a pavement as a result of the design aircraft pass level.

(10) Pass-per-coverage ratio. The number of passes required to produce one coverage.

(11) Jet fuel resistant (JFR) materials. Materials, such as pavement joint fillers, which are designed to resist the effects of fuels used in jet-operated aircraft.

b. Symbols. A graphic representation of typical pavement symbols can be found in figure 1-1.

A_p Cross-sectional area of pavement, square inches, per foot of pavement width or length

A_s Cross-sectional area of reinforcing steel, square inches, per foot of pavement width or length

b Thickness of nonstabilized base course, inches

c,r,f Subscripts used to denote that the thickness of rigid pavement is concrete (JC), reinforced concrete (JRC), or fibrous concrete (JFC), respectively (i.e., h_{dc} denotes required thickness of JC pavement on subgrade or unbound base)

C Condition factor based upon structural condition of existing rigid pavement immediately prior to application of an overlay for strengthening purposes

CBR California Bearing Ratio, determined in accordance with MIL-STD-621, Test Method 101

E_f	Static modulus of elasticity in flexure, psi (Note: subscripts c and s used to denote concrete and stabilized material or Econocrete, respectively)
f_s	Yield strength of reinforcing steel bar or wire, psi
F	Factor relating controlled degree of cracking allowed in the existing pavement after a nonrigid overlay has been applied
h_b	Thickness of stabilized layer or Econocrete in overlay design, inches
h_d	Required design thickness of new rigid pavement, inches
h_e	Thickness of existing rigid pavement, inches
h_o	Required thickness of new rigid pavement overlay, inches
h_E	Equivalent thickness of rigid pavement, inches
k	Modulus of soil reaction, psi per inch, determined in accordance with MIL-STD-621, Test Method 104 (Note: subscripts s, b, and n often used to denote value on surface of subgrade, base course, or existing flexible pavement, respectively)
k_c	Composite modulus of soil reaction, psi per inch, of layered system containing stabilized soil determined as described herein
L	Length of rigid pavement slab, feet
LL	Liquid limit of soil as determined by MIL-STD-621, Test Method 103
PI	Plasticity index of soil as determined by MIL-STD-621, Test Method 103
PL	Plastic limit of soil as determined by MIL-STD-621, Test Method 103
R	Flexural strength of concrete, pounds per square inch, determined in accordance with ASTM C 78
S	Percentage of reinforcing steel in a reinforced pavement $= A_s/A_p \times 100$
t_d	Required thickness of flexible pavement based upon subgrade CBR

t_o Required thickness of nonrigid overlay, inches (Note: subscripts f and a used to denote flexible or all-bituminous concrete nonrigid overlay, respectively)

W Width of rigid pavement slab, feet

1-4. Investigations preliminary to pavement design. The designer should take advantage of all available existing information on subsurface conditions. Existing boring logs and test data previously taken in the area could give insight into these conditions. Insofar as time allows, conventional explorations and laboratory classification tests should be employed. These tests are similar to those described in MIL-STD-619 and MIL-STD-621. They will be used as appropriate to establish the pertinent soil characteristics and any peculiarities of the proposed site that might affect the behavior of the pavement.

1-5. Subgrade.

a. Exploration. Data from available borings, test holes, test pits, etc., should be used to the advantage possible. As a minimum, the site should be visually inspected for obviously defective soil conditions. Undesirable material such as peat, wet clays or silts, quicksand, or other non-supportive soils will be excavated and replaced with material acceptable for subgrade or base course material. In order to give consideration to all factors that may affect the performance of the pavement, a study of existing pavements on similar subgrades in the locality should be made to determine the conditions that may develop in the subgrade after it has been used under a pavement. The engineer is cautioned that such factors as ground water, surface water infiltration, soil capillarity, topography, drainage, rainfall, and frost conditions may affect the future support rendered by the prepared subgrade or base course. Experience has shown that the subgrade will reach near saturation, even in semiarid and arid regions, after a pavement has been constructed. If conditions exist that will cause the subgrade soil to be affected adversely by frost action, the subgrade will be treated in accordance with the requirements of EM 1110-3-138.

b. Compaction requirements. Subgrade soils that gain strength when remolded and compacted will be prepared in accordance with the following criteria.

(1) Compacting fill sections. All fill sections should be compacted to 95 percent of CE maximum density for cohesionless materials and 90 percent for cohesive materials.

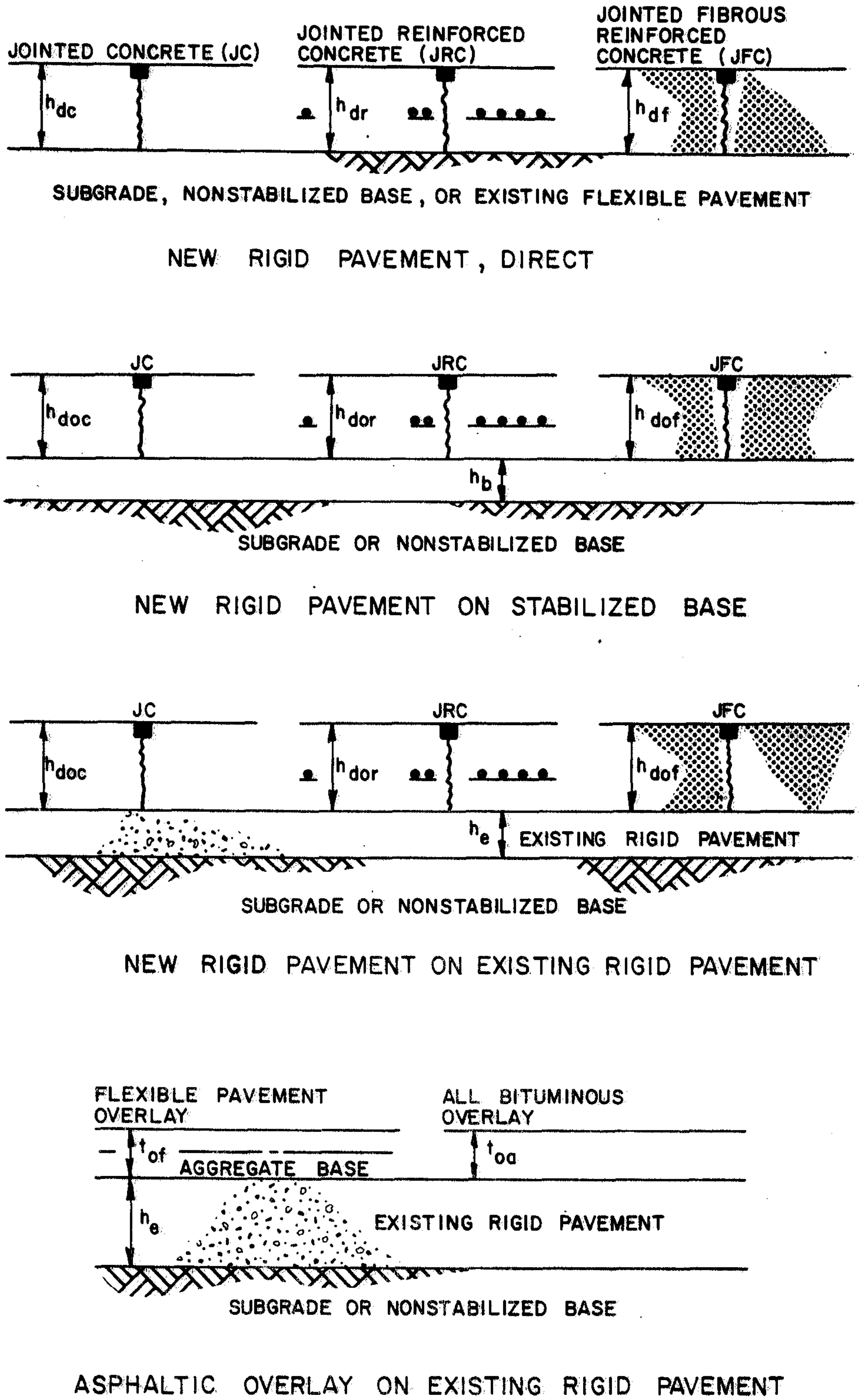

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FIGURE 1-1. TYPES OF RIGID PAVEMENTS

(2) Compacting cut sections. The top 6 inches of all subgrades should be compacted to not less than 90 percent of CE maximum density for cohesive materials and 95 percent for cohesionless materials.

1-6. Base courses. Base courses may be required for one or more of the following reasons: to provide uniform bearing surface for the pavement slab; to replace soft, highly compressible, or expansive soils; to protect the subgrade from detrimental frost heaving; to produce a suitable surface for operating construction equipment during unfavorable weather; to improve the foundation strength (modulus of soil reaction or modulus of elasticity); to prevent subgrade pumping; and to provide drainage of water from under the pavement. When required, a minimum base course thickness of 4 inches will be applied over subgrades. Engineering judgment must be exercised in the design of base course drainage to insure against the trapping of water directly beneath the pavement, which invites the pumping condition that the base course is intended to prevent. Care must also be exercised when selecting base course materials to be used with slipform construction of the pavement. Generally, slipform pavers will operate satisfactorily on materials meeting the base course requirements in paragraph 1-6a. However, cohesionless sands, rounded aggregates, etc., may not provide sufficient stability for slipform operation and should be avoided if slipform paving is to be a construction option.

a. Material requirements. An investigation will be made to determine the source, quantity, and characteristics of available materials. The base course may consist of natural materials or processed materials. In general, the unbound base material will be a well-graded, high-stability material. All base courses to be placed beneath airfield rigid pavements will conform to the following requirements (sieve designations are in accordance with ASTM E 11):

- Well-graded, coarse to fine.
- Not more than 85 percent passing the No. 10 sieve.
- Not more than 15 percent passing the No. 200 sieve.
- PI not more than 8 percent.

However, when it is necessary that the base course provide drainage, the requirements set forth in EM-1110-3-136 will be followed.

b. Compaction requirements. High densities are essential to keep future consolidation to a minimum; however, thin base courses placed on yielding subgrades are difficult to compact to high densities. Therefore, the design density in the base course materials should be the maximum that can be obtained by practical compaction procedures in the field but not less than:

(1) 95 percent of CE maximum density for base courses less than 10 inches thick.

(2) 100 percent of CE maximum density in the top 6 inches and 95 percent of CE maximum density for the remaining thickness for base courses 10 inches or more in thickness.

1-7. Membrane-encapsulated soil layer (MESL). Fine-grained soils that are well compacted at moisture contents below optimum exhibit high strength and low deformability. The MESL is a technique to assure the permanence of these desirable properties by preserving the moisture content at its initial low value. The MESL consists of a layer of compacted fine-grained soil encapsulated in a waterproof membrane that may be used as a foundation for a pavement structure.

a. Materials. The components of the encapsulating membrane normally include polyethylene sheeting, polypropylene fabric, emulsified asphalt, and blotter sand. Sheets of 6-mil or greater thickness of polyethylene are suitable for use as the bottom and sides of the encapsulation. Emulsified asphalt, Grade CSS-1h or SS-1h for warm or hot climates and Grade CRS-2 or RS-2 for cold climates, is used as the prime coat. Polypropylene fabric, emulsified asphalt, and sand are used for the upper membrane to withstand traffic during construction. These materials have been used successfully; however, other materials are available and may be preferred.

b. Construction. Either the in-place or select material can be encapsulated and serve as a subbase or base course material. If the in-place material is to be encapsulated, it must first be removed to the desired depth of encapsulation and windrowed. Subsequent operations are the same for in-place or select materials. MESLs can be constructed in any widths or lengths desired by overlapping sheets of membrane. Laps in the polyethylene should be overlapped a minimum of 2 feet and sealed with emulsified asphalt. Laps in the polypropylene fabric should be overlapped a minimum of 1 foot and sealed with asphalt. The surface on which the membrane is placed should be spray-coated with emulsified asphalt, which will act as an anchor to hold the fabric in place as well as seal for small punctures. Large punctures, rips, or tears in the fabric must be repaired by applying asphalt and covering with membrane. The stockpiled soil is placed on the bottom membrane, taking care that equipment is always operating on a minimum of 10 inches of loose soil. The soil is placed at a moisture content slightly below optimum (2 percent plus or minus 1 percent) and compacted to a minimum of 95 percent CE maximum density. Following fine grading, the surface is sprayed with 0.25 to 0.05 gallon per square yard of asphalt and the polypropylene fabric applied. A final application of 0.2 to 0.3 gallon of asphalt is applied to the fabric and blotted with a dry sand passing the No. 4 sieve. A seal at the edges is obtained by overlapping the polyethylene with the polypropylene for a distance of at least 1 foot and using asphalt between the membranes.

1-8. Soil stabilization or modification. The stabilization or modification of the subgrade and/or base course materials using either chemicals or bitumens has been found desirable in many geographic areas. Principal benefits include the following: reduces rigid pavement thickness requirements; provides a stable all-weather construction platform; decreases swell potential; and reduces the susceptibility to pumping as well as the susceptibility of strength loss due to moisture. Normally, the decision to stabilize or modify a soil will be based upon the time restrictions and materials availability involved.

a. Requirements. To qualify as a stabilized layer (i.e., permit reduction in rigid pavement thickness requirement), the stabilized material must meet the unconfined compressive strength and durability requirements contained in EM 1110-3-137. Otherwise, the layer is considered to be a modified soil. The design of the stabilization or modification will be in accordance with EM 1110-3-137 and EM 1110-3-138. Pavement designs that result in a nonstabilized (pervious) layer sandwiched between a stabilized or modified soil (impervious) layer and the pavement present the danger of entrapped water with subsequent instability in the nonstabilized layer. These designs will not be used unless the nonstabilized layer is positively drained.

b. Evaluation. The foundation support provided by modified soil layers will be evaluated by the modulus of soil reaction k determined after the modifying agent has been added using the procedure outlined in paragraph 1-9. For stabilized soils, the evaluation of the supporting value will depend upon the type of pavement being designed. For example, for JC, JRC, and JFC pavements, the stabilized layer will be considered to be a low-strength base pavement, and the design will be accomplished using a modification of the partially bonded rigid overlay equation as described in chapters 2, 3, and 4. The thickness and flexural modulus of elasticity E_{fs} of the stabilized material will be determined at the same age as for the design flexural strength of the concrete (para 1-10). The flexural modulus of elasticity of cement-, lime-, and fly-ash-stabilized material will be determined in accordance with EM 1110-3-135; for bituminous-stabilized material the flexural modulus will be determined in accordance with EM 1110-3-141. Estimate flexural modulus values if time is not available for testing.

1-9. Evaluation of foundation support.

a. Modulus of soil reaction k. The modulus of soil reaction k, expressed in psi per inch, will be used to define the supporting value of all unbound subgrade and base course materials and all soils that have been additive-modified or encapsulated. The k value will be determined by the field plate bearing test as described in MIL-STD-621, Test Method 104 or estimated from figure 1-2.

(1) Subgrade. The field plate bearing test will be performed on representative areas of the subgrade, taking into consideration such things as changes in material classification, fill or cut areas, and varying moisture (drainage) conditions, which would affect the support value of the subgrade. When it is not practical to perform field plate bearing tests to make a statistical analysis of the k value, a value from figure 1-2 should be assigned. The pavement thickness is not affected appreciably by small changes in k values; therefore, the value need not be sharply defined. Normally, bracketed values will suffice, and the assignment of k values should be in increments of 10 psi per inch for values up to and including 250 psi per inch and increments of 25 psi per inch for values exceeding 250 psi per inch. A maximum k value of 500 psi per inch will be used.

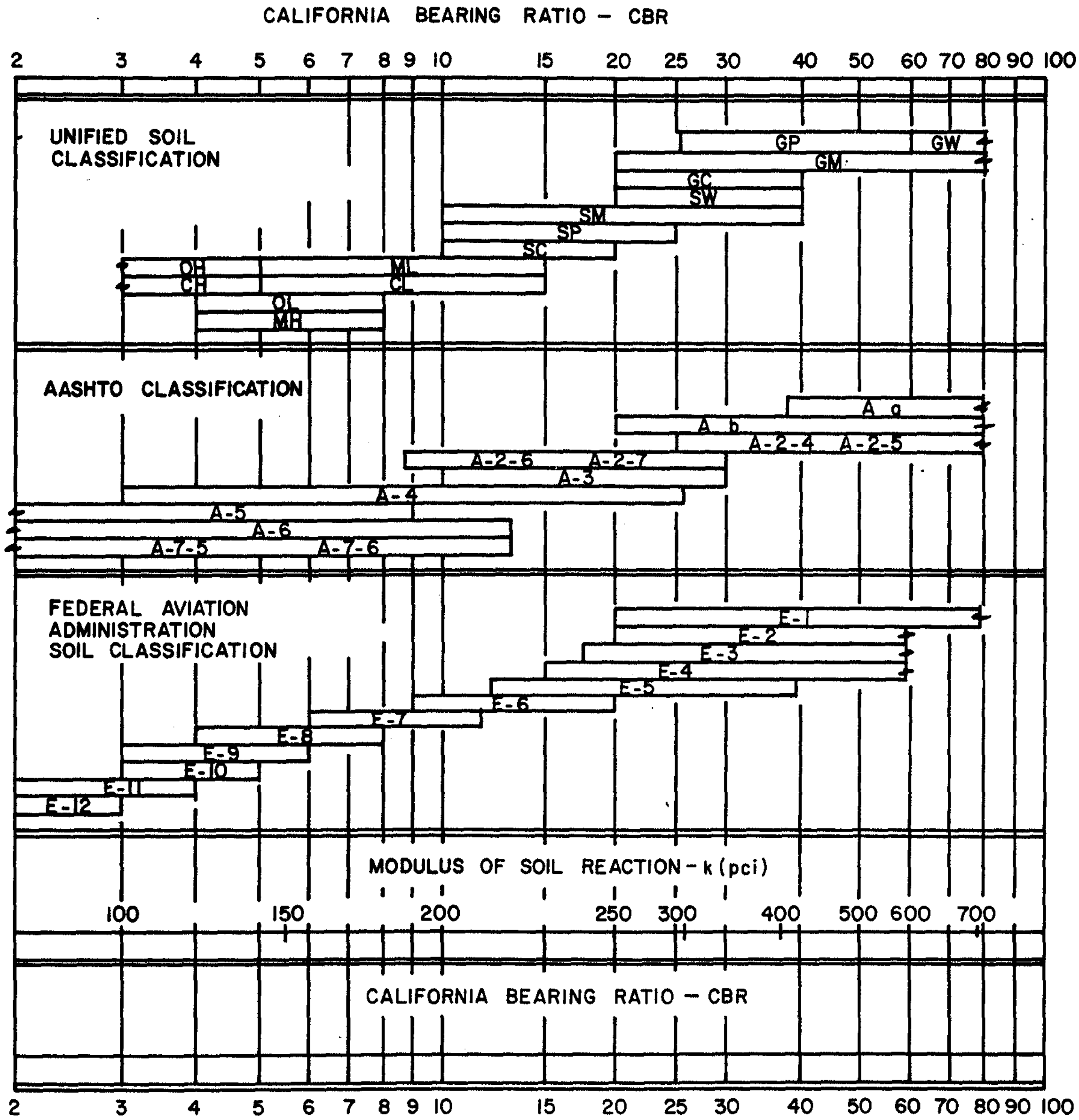
(2) Base courses. The modulus of soil reaction k of unbound base courses will be determined from figure 1-3. The value obtained will be used for the pavement design. Figure 1-3 yields an effective k value at the surface of the base or subbase as a function of the subgrade k value and base or subbase thickness.

b. Composite modulus of soil reaction k_c. For the design of pavements requiring a stabilized layer directly under the pavement, the foundation strength will be defined as a composite modulus of soil reactions k_c. The k_c value is a function of the modulus of soil reaction k of the foundation materials directly beneath the stabilized layer and the thickness and flexural modulus of elasticity of the stabilized layer. With these properties, the k_c value is determined from figure 1-4.

c. Foundation support in frost areas. The procedure for evaluating foundation support in frost areas is presented in EM 1110-3-138.

1-10. Concrete.

a. Stresses. The design of a concrete pavement is based on the critical tensile stresses produced within the slab by the aircraft loading. However, a common and sometimes important source of stress is temperature and/or moisture differential within the slab. The location and intensity of critical stresses produced by a wheel load will vary from point to point depending on the location of the load. The critical concrete tensile stress occurs when the load is adjacent to an edge or joint of the pavement. The stress due to temperature and moisture variation reverses cyclically from top to bottom and may add to or subtract from the stress due to the applied load. Although not



PCA Soil Primer (EB007.068), With Permission of the Portland Cement Association, Skokie, IL.

FIGURE 1-2. APPROXIMATE INTERRELATIONSHIPS OF SOIL CLASSIFICATION AND BEARING VALUES

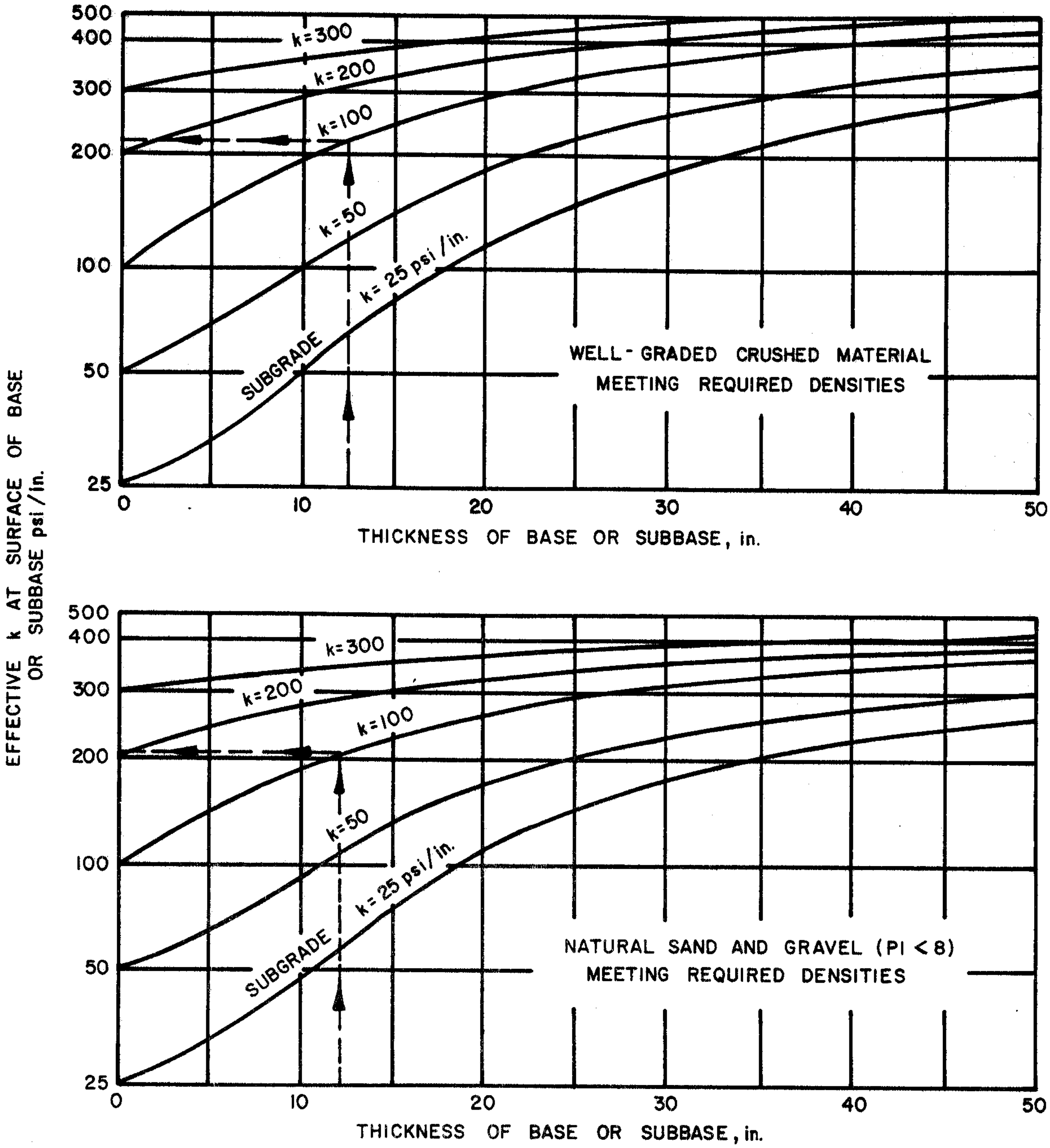


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FIGURE 1-3. EFFECT OF BASE OR SUBBASE THICKNESS ON MODULUS OF SOIL REACTION

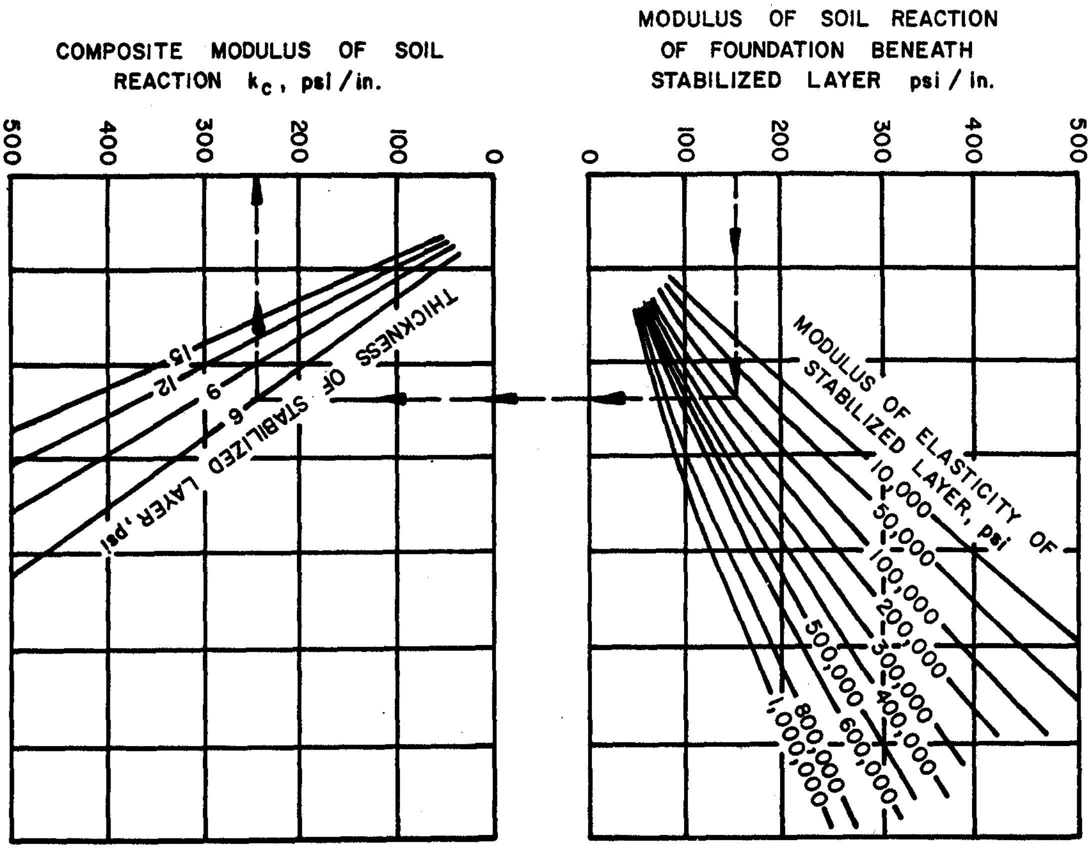

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FIGURE 1-4. COMPOSITE MODULUS OF SOIL REACTION considered independently, the overall effect of these cyclic stresses has been considered in the thickness criteria presented herein.

b. Mix proportioning and control. Proportioning of the concrete mix and control of the concrete for pavement construction will be in accordance with EM 1110-3-135. Normally, a design flexural strength at 90-day age will be used for pavement thickness determination. Should it be necessary to use the pavements at an earlier age, consideration should be given to the use of a design flexural strength at the earlier age or to the use of high early-strength cement, whichever is most feasible.

c. Testing. The flexural strength and modulus of elasticity in flexure of the concrete (and Econocrete) will be determined in accordance with ASTM C 78. The test specimen will be a 6- by 6-inch section long enough to permit testing over a span of 18 inches. When aggregate larger than the 2-inch nominal size is used in the concrete, the mix will be wet-screened over a 2-inch-square mesh sieve before it is used for casting the beam specimen.

1-11. Econocrete. Econocrete is a name given to concrete utilizing locally available crusher-run or natural aggregates. Econocrete may be used as a base course for rigid pavement and may be considered for shoulders or overrun pavements providing the Econocrete can be demonstrated to have the required durability. The mix proportioning, control, and testing of Econocrete will be the same as for concrete (para 1-10). Since Econocrete is designed specifically to provide economy in pavement construction, emphasis must be placed on economy when arriving at the design mix proportioning. Admixtures can be used in Econocrete to increase workability, strength, and durability in the same manner as they are used for concrete. Cement contents in the 225 to 375 pounds per cubic yard range yield economical mixes with good workability. When used as a base course for rigid pavement, the Econocrete will be considered as a stabilized layer and must exhibit the required strength and durability of a stabilized layer. The evaluation of the foundation support provided by the Econocrete will be accomplished in accordance with paragraph 1-8.